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[WDNR] Wisconsin Department of Natural Resources. 2004. Aquatic Communities. Ecological Landscapes of Wisconsin - Ecosystem Management Planning Handbook, HB1805.1.

For more information, please contact:
Jeffrey Schimpff
Environmental Analysis and Review Specialist
PO Box 7921
Madison, WI 53707-7921
Jeff.Schimpff@dnr.state.wi.us
608-267-7853

AQUATIC COMMUNITIES

Community Description

Wisconsin has a large and diverse aquatic resource, ranging from small ephemeral ponds to the largest freshwater lake by surface area in the world. The state is also noted for its plentiful supply of groundwater – two quadrillion gallons of it. Our surface and ground waters directly and indirectly support many species, communities, ecological processes, and human uses.

Wisconsin's aquatic communities were shaped by the last glacial advance, about 11,000 years ago. The weight of glacial ice depressed the earth's crust which rebounded after the glacier melted, forming and reforming drainages and basins. The current physical aquatic landscape emerged about 6,000 years ago.

The last glacier did not cover the Driftless Area in the state's southwestern corner, so that area has a classic branching stream pattern, few natural lakes, and sharper, more eroded terrain. The rest of the state, smoothed by the glacier, has less topographic relief, and sinuous rivers with less average elevation drop. The glaciers also left many natural lakes and spring ponds mainly in the north.

Wisconsin is surrounded by the Great Lakes and the Mississippi River and is drained by 11 large river systems. There are over 57,000 river and stream miles and more than 15,000 inland lakes. In addition, 3,500 dams form lakes and flowages on state waterways (WDNR, 1999).

Inland lakes and ponds. Inland lakes cover more than a million acres, about 9% of the state's land area, and vary greatly in type. They range from a few feet deep to 236 feet deep (Green Lake in Green Lake County) and from small ponds to Lake Winnebago, the state's largest inland lake at 137,708 acres.

Most of Wisconsin's inland lakes are in the north and east. More than 90 percent of the state's total lake surface area is in the 3,620 lakes that are larger than 20 acres (WDNR 2001). About 13% of Wisconsin's lakes are artificial, created by impounding a stream or by excavation (WDNR 2001b). Inland lakes can be subdivided based on:

Depth – deep or shallow. Deep lakes are thermally stratified and experience seasonal turnover twice a year. Shallow lakes are not thermally stratified.

Water chemistry – conductivity, alkalinity, hardness, pH, nutrients, and coliform bacteria.

Physical structure –

- *Drainage lakes* have both an inlet and an outlet and are fed from stream drainage. Artificial lakes created by dams are considered drainage lakes.
- *Seepage lakes* have no inlet nor outlet, are fed by precipitation, runoff, and groundwater from the immediate drainage area.
- *Spring lakes* have an outlet and no inlet, are fed by groundwater into the bottom.
- *Drained lakes* have an outlet, no inlet, are fed by precipitation and direct drainage from the surrounding land. These are the state's least common lake type.

Trophic status (productivity) –

- *Oligotrophic:* abundant dissolved oxygen and relatively low species productivity.
- *Mesotrophic:* moderate nutrient levels and occasional oxygen depletion.
- *Eutrophic:* high productivity, high nutrient levels, and complex ecosystems.
- *Hyper-eutrophic:* degraded habitat with simplified communities, altered species compositions, and dysfunctional ecological processes.

Great Lakes. Wisconsin's Great Lakes shoreline in Lakes Superior and Michigan is approximately 1000 miles long. This shoreline is also the site of Wisconsin's highest population density and the majority of its industrial base. State waters include 1.7 million acres of Lake Superior and 4.7 million acres of Lake Michigan including Green Bay. About a third of Wisconsin's 11 million land acres and a third of its river miles drain to these two lakes.

Lake Michigan, the second largest of the Great Lakes, covers 22,300 square miles. It is a national resource, supplying drinking water for 10 million people and supporting a complex, diverse aquatic system that provides recreational and commercial fishing opportunities and other recreational uses.

Lake Superior, the largest freshwater lake in the world by surface area, covers 31,700 square miles. It is the cleanest and healthiest of all the Great Lakes, having lower levels of development, urbanization and pollution than the other Great Lakes (WDNR 2000).

Lake Superior, the largest freshwater lake in the world by surface area, is the cleanest and healthiest of all the Great Lakes.

Rivers and streams. Wisconsin has 57,000 river/stream miles. The state has distinct regional hydrologic patterns: steep topographic relief and deep cut rivers of the Driftless Area, and the water-rich northern forests with numerous streams, lakes and wetlands. There is a generalized pattern of baseflow dominant, cold water streams on the state's western edge and far northeast corner and scattered in the north central and northwest. These are almost entirely missing from the central and eastern portions of the state (see Figure 1.

River systems are described and categorized by waterbody designations that reflect the aquatic community they support:

- cold water (trout) streams:
    - classes I, II, III, and forage
- warm water sport fish communities
- warm water forage fish communities
- limited forage fish communities
- limited aquatic life communities

Cold water streams support cold-water fish communities with trout or salmon as the top fish predator. Large warm water sport fisheries support systems with bass, walleye, northern pike, or muskellunge as the top fish predators. Small warm water forage fisheries generally support a diversity of forage fish such as smallmouth bass, suckers, minnows, and darters.

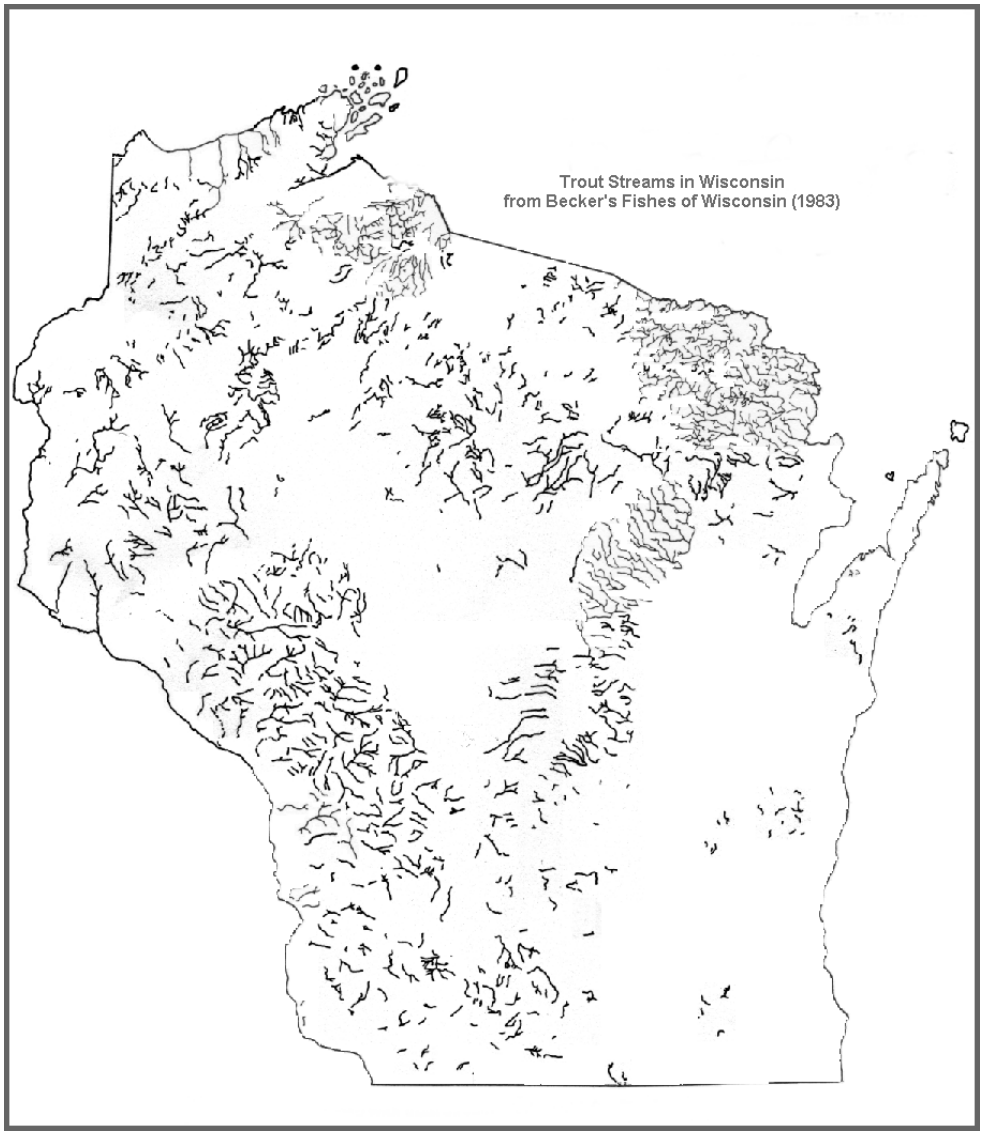
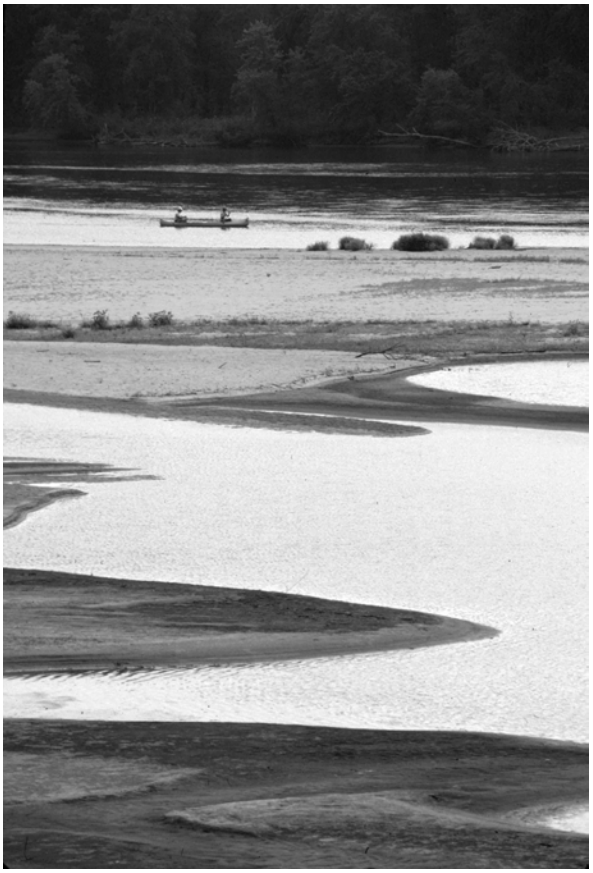


Figure 2. Cold water, base flow dominant streams in Wisconsin

Another way to categorize streams is by flow rate. Large rivers have a mean annual flow of 40 cubic meters per second (cms). Rivers and streams with mean annual flows of 40 cms or less are considered streams (WDNR 1995).

Wisconsin researchers have also developed biotic diversity indices for aquatic systems, which have been used to assess water quality and evaluate macroinvertebrate diversity.



Large rivers. Wisconsin has 11 stretches of large rivers, most of which have been dammed to produce hydropower. These rivers support warmwater fish communities and some of the richest diversity and abundance of freshwater mussels in North America. Wisconsin's big rivers include:

- Mississippi River
- Wisconsin River below Tomahawk
- Chippewa River below the mouth of the Flambeau River
- St. Croix River below the mouth of the Clam River
- Fox River, below the mouth of the Puchyan River and between Lake Winnebago and Green Bay
- Menominee River below the Highway 2/141 bridge
- Rock River below Lake Koshkonong
- Flambeau River below the confluence of the north and south forks
- Wolf River below Shiocton
- Black River in LaCrosse County
- Red Cedar River below Menomonie

The Wisconsin River is one of 11 stretches of large rivers in the state. These rivers support warm water fish communities and some of the richest diversity and abundance of freshwater mussels in North America. Most large rivers have been dammed to produce hydro power.

Groundwater. Groundwater supplies fresh water to the state's streams, rivers, lakes, and wetlands. About 70 percent of Wisconsin's residents use groundwater at home, drawing nearly 195 million gallons of groundwater daily (63 gallons/person/day), and it supplies nearly one third of Wisconsin's business and industrial water needs. Irrigation equipment withdraws about 167 million gallons of groundwater per day during the growing season. Dairy and cattle farms use 78 million gallons per day.

Geology controls the rate of groundwater movement. The size of the cracks in rocks, the size of the pores between soil and rock particles, and whether the pores are connected determine the rate at which water moves into, through, and out of the aquifer. Water generally moves more quickly in coarse sand, sometimes as much as several feet per day, while it may move only a few inches in a year in fine grained clay. Permeability in limestone primarily depends not on pore spaces, but on the size, frequency and distribution of fractures and cracks.

Groundwater is always moving toward a surface outlet such as a lake, river, spring, or wetland. The part of a stream's flow provided by groundwater seeping into it is called baseflow and is critical for providing habitat for aquatic communities. Decreased baseflow results in warmer stream temperatures, degraded water quality, and less spawning habitat for fish.

Groundwater quantity is affected by infiltration rate, land type, land use, and water use. Forests and other densely vegetated areas slow the movement of precipitation across the land's surface, promoting infiltration into the soil. Many land use activities such as agricultural production (particularly where soil is compacted), recently harvested forestland, and developed land with buildings, streets and parking lots, promote runoff rather than infiltration.

Overuse of groundwater can lower the water table (saturated rock and soil area). Pumping pulls water out of the aquifer faster than it can be replenished. This lowers the water table decreasing baseflow to streams and impacting aquatic communities. Groundwater use has significantly lowered the water table in Dane County, Southeastern Wisconsin and the Fox River Valley.

Groundwater quality can be characterized by the same parameters used for lake evaluations: conductivity, alkalinity, hardness, and pH. Groundwater is affected by naturally occurring substances and may be contaminated by substances spread on or leached into the soil. Groundwater quality varies vertically and horizontally within an aquifer and over time. Once contaminated, groundwater is difficult to clean up.

Minerals existing naturally in soils and rocks dissolve in groundwater, giving it a particular taste, odor or color. Some, like calcium and magnesium, are beneficial to health. Others are undesirable: radium, radon gas, uranium, arsenic, barium, fluoride, lead, zinc, iron, manganese, and sulfur. Natural groundwater quality varies across the state and depends on the type of minerals the groundwater has been in contact with. The concentration of natural contaminants depends on how long groundwater has been exposed to the dissolved minerals.

Groundwater contamination can be linked to land use. What goes on the ground can seep through the soil and turn up in drinking water, lakes, rivers, streams, and wetlands. Urban activities that threaten groundwater quality include industrial and municipal waste disposal, road salting, and storage of petroleum products and other hazardous materials. In rural areas animal waste, septic systems, fertilizers, and pesticides are the primary pollution sources. Nitrate is the most commonly detected pollutant in Wisconsin's shallow aquifers. Other common pollutants found in Wisconsin groundwater include pesticides and volatile organic compounds (WDNR 2000).

Special aquatic areas. Special aquatic areas include areas such as fens, bogs, wild rice beds, headwater areas, springs, and groundwater recharge areas. These have distinctive attributes and may support specialized, sensitive aquatic organisms. Even though they may be small in size they often help support larger ecosystems.

Grandma Lake, Florence County. Inland lakes cover about 9% of the state's land area. The concentration of glacial kettle lakes in northern Wisconsin is globally important.

Global/Regional Context

The amount and high quality of Wisconsin's water resources is rare on a global scale. The state's most unique aquatic characteristic may be its geographic position in the Great Lakes system.

Features of national significance in the Great Lakes include the cobble beach community found only along the shoreline of the Door County peninsula; Lake Superior and Lake Michigan drowned bay mouth estuaries found primarily along Wisconsin's shore; the Apostle Islands National seashore located in Lake Superior; and Lake Superior itself – the largest freshwater lake by surface area and the second largest by volume in the world (Hutchinson 1957).

The concentration of glacial kettle lakes within the Northern Highlands-American Legion State Forest is globally important. Some of the lake types there are rare, and many rare organisms are supported by the Highland's waterbodies. (Epstein et. al. 1999)

A number of state and federally listed plants are aquatic or riparian, including the federally threatened Dwarf Lake Iris, *Iris lacustris*. Wisconsin's large rivers contain some of the highest freshwater mussel species richness remaining in North America, including the federally endangered Higgins eye and winged mapleleaf clams.

Issues Of Structure, Function, And Composition

Primary issues of function, structure and composition for all aquatic communities in the state include hydrologic modification, water quality, and exotic species. These result in stream instability and degraded aquatic communities. Harvest pressure and endangered and threatened species are also of concern.

- Hydrologic modification -- The main sources of hydrologic modification include:
    - Intensive development increasing impervious surface area throughout the watershed.
    - Removal or modification of headwater streams which compounds downstream problems by increasing the rate and magnitude of flows, resulting in flashy stream characteristics.
    - Human alteration of a waterbody's riparian zone which removes grasses, plants, tree roots, etc., that would slow and filter water in response to flow variation. The channel narrows, and water speed and volume increase.
- Land use practices such as construction, agriculture, forestry, and other operations disturb soil, promote sedimentation, reduce in-stream habitat, and exacerbate stream instability.
- Poorly managed septic systems and manure storage facilities contribute excess nutrient loads to surface waters when flooded or failed, and even from normal precipitation levels.
- Shoreline zoning regulations that require setbacks and manage development are helping ameliorate this problem for lakes.
- Eurasian Water Milfoil, Zebra mussels, Lamprey eels, and other exotic species overrun, crowd out, and parasitize native species.
- Sport, commercial, and subsistence harvest of aquatic organisms is straining the resources.
- Numerous species of aquatic plants, insects, mussels, snails, reptiles, fish, and birds are endangered or threatened (NHI, 2001).

Great Lakes

- Slow water exchange rates are a significant structural issue for the upper Great Lakes. Lake Michigan has a retention time of 99 years and Lake Superior's is 191 years. As a consequence, pollution impacts on Lakes Superior and Michigan are potentially significant.
- Lake Michigan waters are shared with the state of Michigan; Lake Superior waters are shared with Minnesota and Canada, requiring cooperative management programs.
- Biological diversity is declining in Lake Michigan due to loss of fish species and habitat.
- Lake Superior remains relatively healthy, but is threatened by airborne pollutants as well as waterborne pollutants from local sources.
- The Lakes support primarily cold-water fish communities, but warm water communities exist in littoral and estuarine areas. Both are a mix of native and introduced species. Exotic species have significantly

altered the aquatic community, as have angler harvest and overstocking. Of the seven cisco species once found in Lake Michigan, only the cisco and bloater remain in numbers sufficient to preserve the population. (WDNR 1995)

- Lake Michigan has been dramatically affected by habitat simplification – primarily dredging, wetland filling, water quality declines in estuarine areas, excessive harvest of commercially desirable top predator fish, and pollution. (WDNR 1995)

Inland lakes and ponds

- Lake water levels are affected by wetland loss and land uses that keep precipitation from recharging the groundwater. Groundwater supplies them directly, through springs, or indirectly through stream flow.
- Atmospheric precipitation of mercury, PCBs, and sulfuric acid have affected otherwise pristine lakes far from most human development (Webster 1993).

Rivers and streams

- Over 3,700 dams of varying sizes have been built on Wisconsin's rivers and streams. Dam construction changes river habitats into lake or reservoir habitats. Dams also alter natural flooding and sediment transport patterns and interfere with the contaminant dynamics within aquatic systems.
- Hydroelectric facilities that vary flows to produce electricity for peak demand periods have significant effects on downstream habitats. However, under Federal Energy Regulatory Commission regulations, owner/managers must give equal consideration to the resource as is given to power generation.
- Straightening, channelization, and dredging have altered the structure, function and composition of waterways from the Mississippi River to tiny intermittent streams
- Clearing of woody debris from streams for recreation and other purposes has altered aquatic insect community structures, especially in rivers with a shifting sand bed.

Groundwater

- Groundwater may be affected by naturally occurring or human produced contaminants. Common sources include road salt, petroleum storage, animal waste, septic systems, fertilizers, and pesticides.
- Groundwater withdrawal for drinking water, agricultural, and commercial uses has produced substantial declines in groundwater levels in the Lower Fox River area, Southeastern Wisconsin, and Dane County.
- Lowered water tables permit oxidation of naturally occurring arsenic, allowing it to enter the water.

Special aquatic areas

- Channelization and other changes in the topography around intermittent streams can have significant impacts on crucial headwater regions of the state's rivers and streams.

Muskellunge are the top fish predators in large, warm water sport fisheries. Species rich-ness is one measure of aquatic ecosystem health.

Assessment Of Current Condition

Like terrestrial systems, aquatic systems are subject to simplification and fragmentation. Fragmentation blocks fish migration and movement of other organisms – isolating populations and inhibiting re-colonization. Dam construction, channelization, dredging, rip-rap, mowing shoreline vegetation, perched culverts which disrupt stream flow, and stretches of poor water quality cause fragmentation.

Monitoring, assessing and managing the state's many water resources is a staggeringly large and complex task. The data available on many resources is often outdated or non-existent. The state's database of fish samples offers one method of assessing and indexing surface water status. Indicators of aquatic ecosystem health based on fish community include:

- Presence of fish species intolerant to environmental degradation
- Species richness
- History of extirpations
- Current status of threatened species
- Status of natural reproduction of top-level predators

Water monitoring. Historically the state monitored the physical/habitat, chemical, and biological parameters of waters every five years by doing basin assessments on each basin in the state. There was also targeted or special project monitoring for problem areas or specific projects. The Department has been developing new protocols for baseline monitoring of rivers/streams, lakes and wetland using habitat, fish community, and macroinvertebrate community data.

Future statewide assessments will be statistically based using a random stratified sample. Targeted special project monitoring will still be conducted. Areas on the state's Impaired Waters List will be monitored intensively for

physical, chemical, and biological characteristics to verify their condition and help develop management strategies to bring them back into compliance with water quality standards and designated uses.

Water assessment. The state's waters are assessed regularly and results are reported in Water Quality Management Plans (now called State of the Basin Reports). These reports supply data to Wisconsin's assessment database on all state streams and lakes.

Impaired streams and lakes. In general, Wisconsin's water resource quality is high and improving. Under Section 303(d) of the Clean Water Act administered by the US EPA, Wisconsin has identified a subset of impaired waters -- mostly streams and some lakes -- that do not meet water quality standards or designated uses. The list represents a small fraction of the streams and lakes in the state (WDNR 2000).

Inland lakes -- The number and variety of inland lakes makes it difficult to give an overview of their condition. Local activities and conditions heavily affect these aquatic resources. More than half of Wisconsin's inland lakes could be described as in good to excellent condition based on trophic status and fish communities. (WDNR 1995). Table 1 shows the assessment status of lakes in the state.

Table 1. Lakes assessment data, July 2001 (in acres)

Use	Size assessed	Size fully supporting	Size fully supporting but threatened	Size partially supporting	Size not supporting
Overall use support	345,607	86,526	45,869	108,078	105,134
Aquatic life support	274,336	131,407	40,542	43,297	59,090
Fish consumption	309,240	178,557	22,504	57,906	50,273
Primary contact (recreation)	160,421	17,217	16,480	121,398	5,326
Total	1,089,604	413,707	125,395	330,679	219,823

Overall use support is defined as:

- Fully supporting: all designated uses (which were assessed) are fully supported
- Threatened: one or more uses are threatened and others fully supporting
- Partially supporting: one or more uses are partially supported and remaining uses fully supported
- Not supporting: one or more uses are not supported

Aquatic life support is defined as:

- Supporting: lake does not winterkill
- Threatened: no winterkill, but stunted panfish or carp present
- Partially supporting: no winterkill, but high level of contamination in fish tissue, occupied by Eurasian water milfoil, or turbidity/sedimentation problem
- Not supporting: winterkills

Fish consumption is defined as:

- Supporting: no advisory issued because no contamination was found to exceed state health standards for PCBs, pesticides and mercury; not mercury sensitive
- Threatened: no data available to assess for threatened status
- Partially supporting: advisory; restricted consumption (a limit on the number or size of fish consumed per mean for one or more fish species).
- Not supporting: advisory: no consumption (no consumption by the general population of at least one size class of at least one fish species).

Primary contact (recreation) is defined as:

- Supporting: oligotrophic, mesotrophic or dystrophic
- Threatened: oligotrophic or mesotrophic, but nuisance densities of plants or algae, or phosphorus sensitive
- Partially supporting: eutrophic, turbid or has nuisance densities of plants or algae
- Not supporting: hyper-eutrophic

Great Lakes. Many parts of the Great Lakes shoreline have been modified by urban, industrial, and second-home development; shoreline protection efforts; and changing water level fluctuation cycles. These have affected the dune and coastal marsh systems. Contaminants are commonly found in many Lake Michigan and Lake Superior fish at levels that require consumption advisories, but levels have been declining since the 1970s.

Fish communities in Lake Michigan are disturbed and unstable. The lake has been dramatically affected by habitat simplification. Lamprey eel predation, water quality degradation, introductions and invasion of exotics, and over-fishing have all affected fish populations. (WDNR 1995).

Fish communities in Lake Superior, though heavily exploited, are more stable with significant natural reproduction of most trout and salmon species. Lake Superior is home to the only known population of pygmy whitefish east of the Rockies. (WDNR 1995)

Rivers and streams. Wisconsin rivers and streams remain relatively healthy. Of the state's more than 57,000 miles of perennial and intermittent streams (both navigable and non-navigable), about 23,000 river miles have been formally assessed for aquatic life use support. Of these assessed miles, 7,858 are fully meeting their aquatic life use, 4,425 are fully meeting their aquatic life use but this quality is threatened from pollution, and 10,465 stream miles are impaired.

Rivers exhibit the highest species richness of all the aquatic communities, averaging 14 species with a range of one to 40 species per station. Nine state endangered fish species and 11 state threatened fish species currently inhabit these waters. River mussels, however, have been dramatically affected in abundance and distribution. Three are extirpated. Two have only remnant populations. Two are on the federal endangered species list.

Stretches of the state's major rivers show significant water quality degradation. Conditions in the Mississippi River have improved over the last two decades, primarily due to point source pollution abatement. The Wisconsin River has also improved substantially since its lowest condition in the 1950s and 1960s.

Pike River, Marinette County .Wisconsin's rivers remain relatively healthy. Cold water streams support trout or salmon as the top fish predator

Dams. There are over 3,500 dams on Wisconsin waterways, a third of them classified as large. Dams range from large structures on the Mississippi built to maintain navigation channels for barges to small water-level control structures in marshes. Few new dams are being built, but renovation and expansion of existing dams is common.

Over 30 dams have been removed from the state's waterways in the last 20 years, mostly based on economic considerations. Removal has considerably improved water quality, habitat, and biodiversity at many sites.

Groundwater. Groundwater quality varies greatly throughout Wisconsin. The primary human-caused contaminants of concern are VOCs, nitrate and pesticides. Natural constituents which may present health concerns include iron, manganese, sulfate, arsenic and radium.

Microbial contaminants (viruses, bacteria and parasites) are also increasingly becoming a concern.

Groundwater quantity and water withdrawal issues are receiving more attention. The state has limited authority in regulating groundwater withdrawals that may affect surface water resources.

Land Use And Environmental Considerations

Laws. Wisconsin surface and ground waters are managed and protected under a variety of federal, state, and municipal regulations. Under Wisconsin Law, Chapter 281, Wis. Stats., the DNR is the central unit of government to protect, maintain, and improve the quality and management of the waters of the state: ground and surface, public and private.

Groundwater laws. Wisconsin has a long history of groundwater protection. Wisconsin's Comprehensive Groundwater Protection Act, signed into law in 1984, created Chapter 160, Wis. Stats. The major program components include:

- State groundwater standards (chapter NR 140, Wis. Adm. Code).
- Once groundwater quality standards are established, all state agencies must mandate their regulatory programs to comply.
- All groundwater in Wisconsin must be protected equally to assure that it can be used for people to drink today and in the future.
- A groundwater monitoring program (s. 160.27, Wis. Stats.).
- Groundwater research.
- The Groundwater Coordinating Council to help with coordinating non-regulatory programs and exchanging groundwater information.
- Clarified powers and responsibilities of local governments to protect groundwater in partnership and consistent with state law.

Non-point source pollution (runoff) rules. The Legislature has directed creation of administrative rules establishing performance standards to control polluted runoff from agricultural, urban and transportation areas; describe implementation strategies; and lay out grant procedures to pay for implementation. When adopted this approach will eventually replace priority watershed projects that have been the state's primary vehicle for non-point source control since 1978. Priority watershed projects will continue until all projects are completed, which is estimated to be 2009.

Proposed agricultural performance standards to control soil loss from croplands include buffers along waterbodies and proper management of manure and other nutrients (including those previously developed by the Animal Waste Advisory Committee).

Proposed non-agricultural performance standards would include:

- Using erosion control plans on construction on sites of five acres or more (one acre in 2003).
- Implementing storm water management plans on those sites.
- Public education on controlling polluted runoff from residential lawns and gardens.
- Restricting fertilizer and pesticide restrictions on turf areas greater than five acres.
- More street sweeping to reduce suspended solids

Transportation performance standards are similar to the non-agricultural standards and would apply to roads and other transportation sites.

For more information, see the Runoff Management web page at http://www.dnr.state.wi.us/org/water/wm/nps/index.htm.

Urbanization and development. In urban and developed areas rainfall runs off paved surfaces directly into surface water rather than infiltrating through the soil to groundwater. Baseflow to streams decreases and some streams and lakes may even recharge the groundwater. This is currently happening in Dane County where water is being drawn into the aquifer from Lakes Mendota and Monona. Increasing runoff also raises surface water temperature and water levels. Stream levels respond more quickly to rainfall events, becoming "flashy" and resulting in more flooding.

Recreation. Aquatic systems attract considerable use for recreation and second home development.

- Conflicts can occur between incompatible uses, such as water-skiing and fishing, and between statewide users and the local residents and owners of riparian lands.
- Recreational fishing from Wisconsin's large fishing public (among the five largest in the nation) stretches the resource and creates demands for intensive fishery management and more access.
- Boats and boating can directly impact habitat with discharge of raw fuel, oils, and combustion byproducts. Heavy boat traffic disturbs vegetation and macroinvertebrate production and causes shoreline erosion and sediment resuspension. Boat traffic also disturbs waterfowl and other aquatic wildlife.

Fish stocking. There is growing evidence that fish stocking, transfers, and new species introductions have a long-term negative impacts on the growth, survival, reproduction, and health of both existing and stocked fish. Release of bait fish and macroinvertebrates is also a source of genetic mixing.

Harvest. Sport, commercial, and subsistence harvest of aquatic organisms is substantial. Regulated sport angling affects the relative abundance of older, larger fish.

Herptile harvest is reducing populations of some species (the state-threatened wood turtle popular for the pet trade, large snapping turtles).

Invasion of exotic species. More than 140 exotic aquatic organisms of all types have become established in the Great Lakes since European settlement began. In addition to the well-known Zebra Mussel and Sea Lamprey they include fish (Common Carp, Goby, Ruffe, White Perch), crustaceans (*Cercopagis pengoi*, Rusty Crayfish, Spiny Water Flea), and plants (Curly-leaf Pondweed, Eurasian Watermilfoil, Flowering Rush, and Purple Loosestrife) (GLIN 2001). Eurasian water milfoil has now spread to at least 75 inland lakes in 39 Wisconsin counties. For more information see the Great Lakes Information Network website at:
http://www.great-lakes.net/envt/flora-fauna/invasive/invasive.html#overview (exit DNR)

Statewide Ecological Opportunities And Opportunities By Ecological Landscape

During 2001, each of the DNR's GMUs and Basins will complete a State of the Basin Report describing goals, objectives and recommendations for preservation and enhancement of the state's land and water resources. They will be used to develop this section at a later time.

Table 2 shows the relationship between the state's GMUs/Basins and its ecological landscapes. Overlays and maps in the Statewide Maps section of this Handbook represent these relationships graphically.

Maps And Data Sources

The following maps in the Statewide Maps section of this Handbook can be useful:

303d degraded lakes and rivers
Outstanding and exceptional lakes and streams
Depth to water table
Susceptibility to groundwater contamination

Geographical Management Units overlay
Major lakes and rivers overlay

The following web pages have data and information about aquatic communities:

Endangered Species. WDNR. *Available at:* http://www.dnr.state.wi.us/org/land/er/rare.htm

Great Lakes Information Network. 2001. [GLIN 2001]. US EPA.
http://www.great-lakes.net/envt/flora-fauna/invasive/invasive.html#overview (exit DNR)

Invasive Species website. WDNR. http://www.dnr.state.wi.us/org/land/er/invasive/indes.htm

Natural Heritage Inventory. WDNR. Describes natural communities including several aquatic communities such as bedrock shore, emergent aquatic, ephemeral pond, and submergent aquatic.
http://www.dnr.state.wi.us/org/land/er/rare/natcomm_descripts.htm

Wisconsin Lakes. WDNR. http://www.dnr.state.wi.us/org/water/fhp/lakes/lakeinfo.htm#lakebook

Table 2. GMUs by Ecological Landscape

GMUs by Ecological Landscape	Superior	Northwest	Northwest	North Central	Northern	Northeast	Forest Transition	Northern	Western	Central	Western	Central	Southwest	Southern	Southern	Central	Total Ecological Landscapes in GMU
BLACK-BUFFALO-TREMPEALEAU				x			x			x	x						4
CENTRAL WISCONSIN							x			x	x	x					4
GRANT-PLATTE-SUGAR-PECATONICA											x		x	x			3
HEADWATERS				x	x	x	x										4
ILLINOIS FOX														x	x		2
LA CROSSE BAD AXE										x	x						2
LAKE MICHIGAN								x							x	x	3
LAKE SHORE								x						x		x	3
LAKE SUPERIOR	x	x	x	x	x												5
LOWER CHIPPEWA				x			x		x	x	x						5
LOWER FOX								x						x		x	3
LOWER ROCK												x		x			2
LOWER WISCONSIN										x	x	x	x	x			5
MILWAUKEE														x	x	x	3
MISSISSIPPI-LOWER ST. CROIX									x		x						2
ROOT-PIKE														x	x		2
SHEBOYGAN														x		x	2
ST. CROIX		x	x	x			x		x								5
UPPER CHIPPEWA			x	x	x		x		x		x						6
UPPER FOX										x		x		x		x	4
UPPER GREEN BAY				x		x	x	x								x	5
UPPER ROCK												x		x			2
WOLF						x	x	x		x		x		x			6
Total GMUs in Ecological Landscapes	1	2	3	7	4	3	8	5	4	7	8	6	2	12	4	7	

Recommended Reading And References

Epstein E, W Smith, J Dobberpuhl, A Galvin. 1999. *Biotic Inventory and Analysis of the Northern Highland-American Legion State Forest*. Wisconsin's Natural Heritage Inventory Program, Bureau of Endangered Resources, Department of Natural Resources. Madison, WI.

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